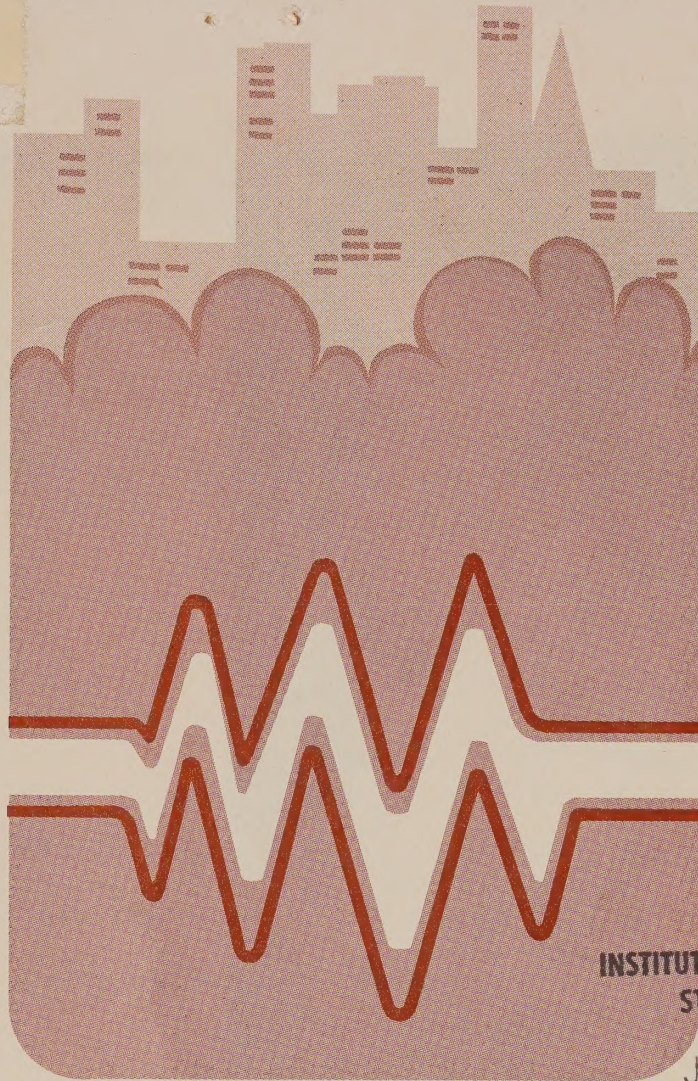


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STUDIES

JUN 7 1976

UNIVERSITY OF CALIFORNIA

LAND CAPABILITY ANALYSIS FOR PLANNING AND DECISION MAKING

Conservation Soil SF bay
Land Util. area



USGS Photo

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This booklet is based on a draft report, "Land Capability Analysis: A Method and Demonstration Applying Earth Science Information to Housing and Urban Development," prepared by the Association of Bay Area Governments under the joint sponsorship of the U.S. Geological Survey and the U.S. Department of Housing and Urban Development. The document is currently under review; the statements and conclusions contained herein do not necessarily reflect the views of the sponsoring agencies.



San Francisco — 1906

USGS Photo

LAND CAPABILITY ANALYSIS FOR PLANNING AND DECISION MAKING

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WHY ANALYZE LAND CAPABILITY?

A land capability analysis attempts to make earth science information more useful to local governments and their decision makers, and makes planning more responsive to this information. As used here, "land capability" means the ability of land to accommodate a particular land use with an acceptable level of geologic and hydrologic costs.

In recent years, land use planners have been paying closer attention to geologic considerations. Even so, earth science information is still not adequately incorporated in most land use planning and decision making. The principal reasons for this problem are that such information is often inadequately interpreted by geologists and hydrologists, and equally often planners do not properly integrate the information into the planning and decision-making processes.

In recent years, however, major steps have been taken toward overcoming these deficiencies, since earth scientists have begun to produce interpretive maps of specific geologic constraints and resources. For instance, as part of the San Francisco Bay Region Environment and Resources Planning Study, the U.S. Geological Survey shows slight, moderate, and severe landslide potential rather than just the presence of geologic materials or landslide deposits. But most interpretive maps still do not provide sufficient information for planners, because:

1. Earth science problems cannot be easily compared with other environmental and social considerations, since the maps do not reflect the relative importance of geologic resources and constraints.
2. Individual maps dealing with only one factor -- say landslides, or liquefaction potential -- cannot point up the relative importance of constraints or resources. For instance, they do not indicate whether it is more hazardous to build on a floodplain or in a landslide-prone area.
3. The degree of a constraint differs for different land uses. Thus, for example, slight, moderate, and severe landslide potentials for low-density residences differ from rankings for apartment buildings.

Because of these and other difficulties of interpretation, some planning documents simply do not include earth science information. Even when the effort is made to integrate geologic considerations, planners often concentrate on just one factor, using it as a rough indicator of all earth science problems. If, say, a planning study considers only percent slope, potentially important considerations such as liquefaction and flooding may be ignored. Furthermore, capability studies may be based on a single concern that is felt to be of overriding significance, and land use choices are then resolved in terms of this one issue.

Another problem is that many planners view earth science concerns strictly as "go" or "no go" signals for proposed developments. If there are only slight earth science problems, this is taken to mean that development can be unrestricted. If, on the other hand, there are severe geologic constraints, no development is allowed. The number of planning options is therefore unnecessarily limited.

To bring more flexibility to land use planning and decision making, earth science information should be provided for several land uses, so that the constraints and opportunities of different alternatives can be analyzed and compared.

The state of the art of land capability planning needs to be advanced to make earth science information easier to incorporate into the total planning process. To this end, the Association of Bay Area Governments (ABAG), under the sponsorship of the U.S. Geological Survey (USGS) and the U.S. Department of Housing and Urban Development (HUD), has developed a method for land capability assessment. This method should enable local jurisdictions to use the earth science information provided by USGS and other agencies. The complete report contains a more detailed description of the demonstration which should allow local planning staffs to duplicate the method. The method has been demonstrated using the Santa Clara Valley area. This booklet summarizes the steps in the analysis, and highlights some of the important points in the demonstration of the method.

WHAT IS A LAND CAPABILITY ANALYSIS?

Land capability

As stated earlier, "land capability" means the ability of land to accommodate a particular land use with an acceptable level of geologic and hydrologic costs. Earth science considerations fall into two categories -- constraints and resources. Constraints include hazards such as ground shaking from earthquakes and development problems such as shrink-swell soils. Resources include such things as mineral deposits, energy resources, construction material deposits, and prime agricultural land.

Estimating costs

In the ABAG study, land capability is assessed by estimating, for different types of land uses, the social costs associated with each relevant earth science constraint and resource. "Social cost" as used here means the sum of all apparent costs attributable to an earth science concern, regardless of who pays. There are three basic types of costs:

- A. Study, engineering, design, and mitigation costs. These costs are usually incurred before or immediately upon construction of a project.
- B. Disaster or damage costs that must be paid (usually in the future) when damage occurs.
- C. Opportunity costs -- the revenues or benefits that would have resulted from one type of land use that are foregone if the land is used for something else.

These costs differ for different places and for different land uses. Lower values of expected cost indicate a greater capability of the land to support the indicated land use.

Using cost to rank the relative importance of various geological conditions makes it possible to compare resource losses with potential property damage. Various types of land use can be assessed separately. Also, costs related to geologic or hydrologic problems can be readily compared with most public costs, such as those for infrastructure.

WHO CAN USE LAND CAPABILITY ANALYSES?

Decision makers

Land capability analyses provide important information for weighing alternatives and making land use choices in conjunction with other environmental and social information.

Planners

Land capability information can be used with other developmental information in the development of planning criteria and policies and in the identification of significant geologic constraints and resources. Land capability analyses can be readily incorporated into development regulations, environmental reviews, and other implementation plans. Results of the analyses make it possible to establish priorities for time, effort, and funding of future research -- in effect, for defining the significance and/or severity of problems.

Public works engineers

Land capability analyses can be used to help identify areas where special development ordinances and regulations may be needed, or where special construction standards should be set.

Developers

Land capability information is useful in evaluating site proposals before land acquisition, and in determining what additional studies, design, or engineering may be needed.

Architects and builders

Land capability analysis promotes better design, because response to requirements is based on detailed site information and a clear understanding of constraints.

STEPS IN THE ANALYSIS

The first step in the capability analysis is to select the geologic constraints or resources thought to cause significant costs for different activities on the land in question. This step involves collecting earth science information and preparing basic data maps. In Step 2, interpretive maps are developed for each consideration, either directly from an appropriate basic map or by combining maps. The interpretive maps can then be used to describe specific problems.

In Step 3, social costs (in dollars) are calculated for each type of development and each earth science concern. Costs that accrue at different times are made commensurable by calculating the present value of future costs, using an interest, or discount, rate. Costs that occur at some unknown future time are calculated by finding the average (or expected) value of the costs.

The next step is to total all the expected costs for all the conditions for each land use. This total is used as an indicator of the capability of the land to accommodate each use. Then, when the sums of these costs are displayed spatially, capability maps are produced for each land use. This is the final step in the procedure, and the capability assessment can now be used in the planning and decision-making processes.

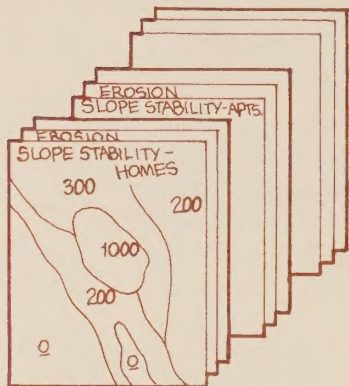
As mentioned earlier, earth science effects can be considered in terms of constraints and resources. In the Bay Area, a number of these considerations are of particular concern in land use planning.

CONSTRAINTS

Earthquake problems

Direct earthquake damage may result from ground shaking or fault rupture. The extent of ground shaking damage depends on the severity of the shaking and on how susceptible to damage the buildings in the area are. Fault movement, which commonly occurs during earthquakes in California, may destroy or deform structures built across the fault. Vertical, horizontal, or both types of displacements may occur, and may range from a few inches to several feet.

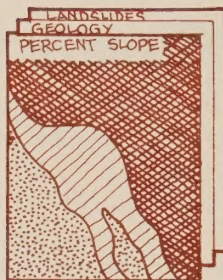
STEPS IN LAND CAPABILITY ANALYSIS



3

Cost indices

Assign a numerical dollar value to the various categories of each resulting map to indicate the relative importance of that constraint or resource for each land use considered.



1

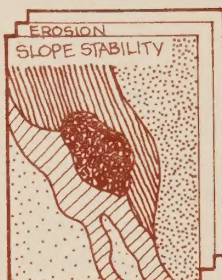
Basic data maps

Collect basic earth science information on the land.

2

Interpretive maps

Compile maps for each earth science concern directly from the appropriate map or combination of maps.



4

Total cost

Add the cost indices for all the conditions found for each land use.

5

Capability maps

Divide these cost numbers into categories to be mapped for different land uses. Lighter shades represent lower costs and higher relative capability.



Slope stability

Landslides, a particular problem in parts of the Bay Area, are rapid downhill movements of soil or rock. Road building, landscape watering, and similar development-related activities may increase the size and frequency of landslides. Earthquakes may also trigger landslides, particularly during or after a rainy season. Another slope stability problem is soil creep -- the slow, almost imperceptible movement of earth. Even though such movement may be only a few inches a year, it may still rupture pipes, fracture foundations, and eventually destroy buildings.

Flooding

Flooding is a problem that is accentuated by development upstream. Heavy rains may cause streams to overflow and inundate floodplains. Urban development in such an area increases the impervious surface area and thus leads to greater runoff and more frequent flooding. Flooding may also occur if man-made dams, levees, or dikes fail. Sudden failure can destroy all buildings and kill or injure many people in the immediate path of the water. Even a slower rate of failure can cause serious problems.

Bearing materials problems

Subsidence, an area-wide lowering of the ground surface, can be caused by cultivating peat soils (as in the Delta area) or by the withdrawal of natural gas, oil, groundwater, steam, minerals, and so on. If subsidence is not uniform, or if it increases susceptibility to dike or levee failure, considerable damage may occur.

The densification of soil may cause settlement -- a lowering of the ground surface -- which can be accelerated by the shaking accompanying earthquakes. Settlement can damage structures, and differential settlement may do extensive damage because of the unevenness of the densification.

In the liquefaction process, loose, water-saturated sands and other granular materials suddenly lose strength when they are shaken by earthquakes or for other reasons. The resultant lurching and sliding of the ground may severely damage buildings.

On relatively flat ground, expansive soils -- soils that contain clays that expand when wet and contract when dry -- have shrink-swell potential. These expand/contract properties can cause heaving, cracking, and break-up of pavements and concrete foundations. They can also displace and break pipes; in the case of sewer pipes, pollution can result.

Erosion and sedimentation

Weathered rock or soil may be transported by forces of gravity in down-slope movement, or by moving water in slope runoff and stream transport. Erosion can also be caused by ocean waves and strong winds. Development activity may increase erosion many times over the natural levels. Erosion may result in severe agricultural soil losses, damage to structures, property loss, and degradation of stream water quality.

The transported soil is eventually deposited elsewhere. Such sedimentation may fill reservoirs, clog drains and gutters, and overload stream channels.

Land pollution

Land may become contaminated because of poorly designed and operated landfills or from sewage disposal systems (including septic tanks). When this happens, water pollution may also result.

RESOURCES

Minerals

Development that prevents mining valuable mineral deposits can be costly for society. If there are few substitutes for certain minerals, and if they exist in only limited amounts in the United States, they may be considered "strategic" resources. There are many mineral deposits in the Bay Area, and some of them (mercury, chromite, and manganese) are in limited supply in this country.

Construction materials

Sand and gravel are essential for almost all development activities. Other resources such as crushed rock, salt, and dimension stone are also valuable.

Energy resources

Geothermal and hydropower resources are particularly important because they are permanent, long-term energy sources, but more traditional sources (coal, natural gas, petroleum) must also be considered. Geologic and hydrologic considerations are especially critical in siting nuclear reactors -- the site must be stable and safe, there must be an abundant cooling water supply, and protective measures are required for disposing of the heated cooling water.

Agricultural land

Prime agricultural land is an exhaustible resource. As such, it is often more valuable than land which does not lend itself so well to growing crops. Agricultural land uses are especially important considerations in the nine-county Bay Area.

COLLECTING DATA

After the significant earth science topics have been chosen, basic information can be collected. Information that helps in estimating cost will be most useful. Thus, for example, for analyzing landslide potential a map showing relative slope stability is more useful than one that shows percent slope, since landslides result in direct costs, but slope per se does not. Efforts should also be directed to obtaining basic maps at scales appropriate to their final use, since enlarging mapped information may lead to misapplication of the information content of the original.

Maps depicting geologic information can be obtained from many sources, the most common ones being the U.S. Department of Agriculture Soil Conservation Service, the USGS, the U.S. Army Corps of Engineers, state departments of mining and geology, water and utility districts, and colleges and universities.

PRODUCING MAPS

Maps that lend themselves to developing cost estimates may not always be available. Such maps can sometimes be produced by overlaying two or more maps. As an example, a landslide potential map can be built up from a map of photointerpreted landslides, a geological map, and a percent slope map.

ASSESSING COSTS

A key step in the analysis is relating earth science considerations in terms of dollar costs for each land development alternative. Since several geologic problems usually pertain to a given parcel of land, there must be a method for weighing the relative importance of seemingly incommensurable factors -- in effect, one must compare apples and oranges.

For example, consider land settlement and earthquake-caused ground shaking. Settlement occurs continuously over a long period, and the resultant costs are usually absorbed by the land owners. But ground shaking is a rare and random event, whose costs are often at least partially borne by government at all levels. Determining the number of earthquakes that equals the cost of a given degree of land settlement therefore poses a fundamental problem.

Dollars as a unit of measure

A useful approach to resolving the "apples and oranges" dilemma is to estimate, for each land use, all the dollar costs associated with each geologic problem, and then to sum the costs for all problems. It is generally thought that the price (or cost) of an item reflects the relative value people place on that item. Thus if apples cost a dime and oranges cost a nickel, an apple is worth two oranges. In much the same way, geologic considerations can be compared in dollar terms. Of course, a comparison only of the costs due to geological problems, with no attempt at assessing the relative benefits of each land use alternative, does not give all the information needed for decision making. A complete analysis would consider other cost/benefit factors and would identify important intangible considerations.

However, the dollar-cost approach yields two important dividends. Because the assumptions are explicit, they can be critiqued and the effects of different assumptions can be tested. This will improve the planning input. Also, the dollar-cost approach will reveal many cost estimates as subject to considerable uncertainty. This is a benefit because it becomes readily apparent what new data must be developed in order to improve those estimates. Thus evaluation and experiment can interact to improve the information available to planners and decision makers.

One problem with the dollar-cost approach is that many environmental factors are characterized by external effects or are public goods. This means that one man's actions at one place affect other people at other places, and that these effects are not mediated by any market interaction. The textbook example of such an external effect is air pollution. Each person who operates an automobile imposes a cost on others in terms of lowered health and unsightly skies, and no institution requires automobile operators to compensate those who are so affected. It is widely agreed that the absence of markets precludes any reliable estimation of the dollar costs associated with such public goods.

If a large share of earth science-related costs were of the public good/external effect type, there would be little advantage to adopting the dollar-cost approach, since cost estimates would be largely intuitive in any case. There are exceptions to this, to be sure; erosion and sedimentation, land pollution, and stream flooding are examples of earth science considerations that have at least some element of external cost associated with them. In spite of these problems, it is felt that, in general, most earth science costs are well suited to a dollar-cost approach.

The product of the next step in the analysis is a spatial representation of the costs related to earth science, for each land use. The lack of external effects makes such a representation possible. If external effects were important, one could only speak of total costs associated with a given pattern of development for the entire region or subregional area in which the external effects occurred. For example, in considering air pollution one must deal with the costs for the entire air basin -- it is not possible to point to a particular site and say that there is an air pollution cost of \$9,000 per acre associated with the construction of apartments there, because this cost depends on the amount and kind of development elsewhere in the air basin also.

A simple corollary of this argument is that the land capability analysis method, with its spatially assigned costs, cannot be extended to environmental problems that have important external effects, including air or water pollution, crowding, or the general quality of life.

Total dollar cost as a measure of social cost

Costs due to geologic factors are incurred by different persons and agencies. It must be decided which of these costs to count, and how they should be aggregated. In the ABAG study, total dollar cost, regardless of who pays, was used. This simple approach (and its more sophisticated relative, cost/benefit analysis) cannot be used of itself for making land use decisions; the political process is still necessary, since there are many considerations which do not readily lend themselves to reliable quantification.

Incorporating effects of time and uncertainty

A way must be chosen for incorporating the effects of time and uncertainty into the analysis, because:

1. The costs of different earth science concerns occur at varying times in the future. These costs must be aggregated, and an allowance must be made for differing values of money over time.
2. Many earth science-related costs are subject to risk -- that is, one cannot say with certainty when (if ever) the event that causes damage will occur. Instead, only a probability of occurrence can be specified. Therefore, the question of risk preference must be resolved.

These choices affect both the cost estimates and the relative importance of the earth science topics. Since they all must be value judgments, there is no one correct answer. In general, the simplest solution will suffice to proceed with the analysis.

Discounting was selected in order to compare costs that occur at different times in the future. Discounting, as used here, is the process of reducing the value of some future dollar amount to its present value by an amount to cover interest. A subsidiary problem here is the question of which discount rate to use. Advocates of resource conservation and high rates of capital investment favor a low discount rate. Those who would like to see government spending directed to projects with low capital investment, such as social welfare, prefer a high discount rate. In the ABAG study a discount rate of 10% -- close to the present market rate -- was used, as an intermediate value. A lower discount rate would increase damage losses and potential resource losses, and a higher rate would, of course, decrease these costs.

Risk preference choice is based on the concept of expected value -- that is, the expected return on a decision equals the sum of the probability of each outcome times the return if that outcome is realized. But quite different decisions can have the same expected return. For instance, consider making one of two bets: (1) betting \$1 on the flip of a coin 1,000 separate times, or (2) betting \$1,000 on the single flip of a coin. The expected return for each bet is zero, yet many people would clearly prefer one over the other, because the chances of a big loss or a big gain are much greater for the second bet. People who prefer Bet 1 are "risk adverse", those who prefer Bet 2 exhibit "risk preference", and those who have no preference are "risk neutral". For this study risk neutrality -- the assumption that decisions can be based on the expected value of future costs -- was assumed because it was the simplest choice.

Choosing the type of dollar cost to use

For purposes of land capability analysis, there are four types of dollar cost that can be chosen to work with:

1. Opportunity cost -- the cost of the lost resource potential.
2. Study and mitigation cost -- the cost of studies to determine potential damage and of mitigation measures implemented to reduce this potential.
3. Damage cost.
4. No cost -- the assumption that cost will be insignificant, or that there are no known costs.

Many cost estimates depend on the assumptions made about construction practices and preconstruction site investigation. For instance, structural damage related to ground shaking depends on the type of construction. And if a site investigation identifies a potential cost so that mitigation measures may be taken, the appropriate cost associated with the geologic problem is the sum of the costs related to investigation and mitigation.

PREPARING LAND CAPABILITY MAPS

Mapping systems

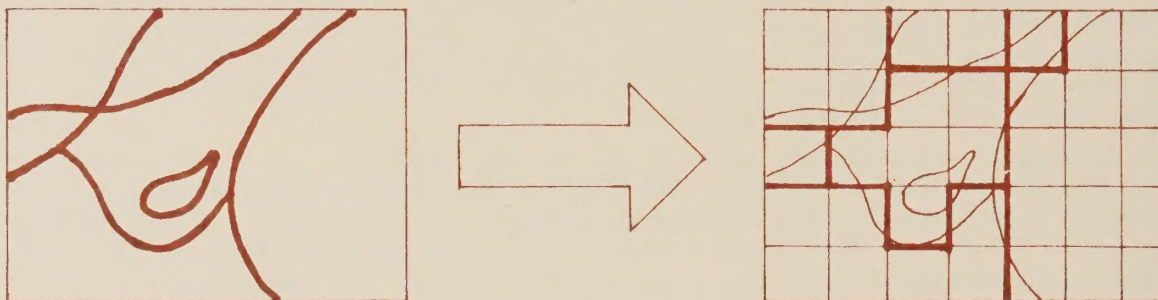
Adding dollar costs for each parcel of land and each land use can be done by hand or by computer. Each method has limitations and advantages.

Hand mapping is cheap (in the short run) and it is a familiar technique. It also allows for inexpensive storage. But hand mapping suffers from lack of accuracy, difficulties of reproduction, problems in overlaying maps, and lack of flexibility in using the results. This latter drawback is a major problem if estimates of expected cost must be changed and refined.

Various software packages for computer storage and processing are available already, and more are being developed. In computer mapping, data can be represented using either grid cells or polygons. Grid cells produce maps which generalize areas into boxes (see Figure 1, below). The smallest cell size that can be used readily is about 1/10 inch square. This size lends itself to the collection of mapped data and to graphic presentation using high-speed line printers.

FIGURE 1

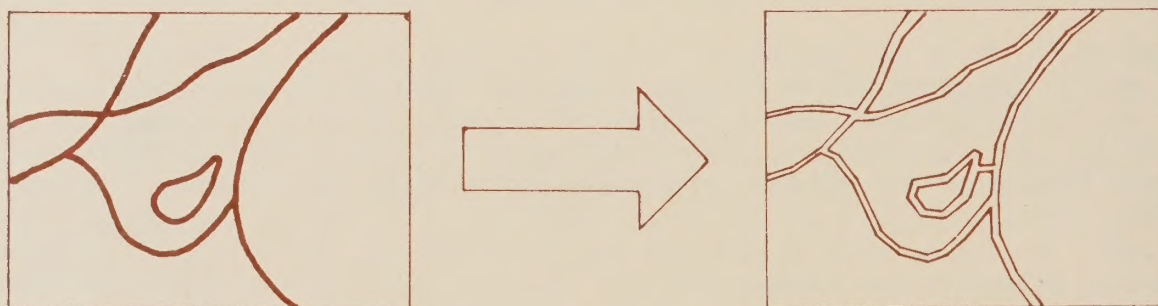
Grid cell representation



A polygon system represents an area by a closed polygon, and can therefore represent curvilinear lines by a series of closely spaced points connected by short line segments (see Figure 2).

FIGURE 2

Polygon representation



Although potentially much more accurate than the grid cell system, editing out discrepancies is a major quality control problem. Since the perimeter of each area must be digitized separately, the boundaries between areas can become either data gaps or data overlaps. If many overlays are needed to produce the composite capability map, the map may be dominated by such errors.

Both types of computer systems have inherent disadvantages. These include high initial costs for map preparation, largely because maps must be digitized manually (with a digitizer) or must be optically scanned. An ideal system would probably combine negative scribed basic data maps, etched on an opaque stable base, with a computer polygon system. This would be expensive, but it would provide excellent flexibility, accuracy, and the potential for carrying out detailed, complicated analyses.

Map scale

The choice of map scale is related to the ultimate use of the material, as well as to the scale at which basic information is available. For county and/or regional considerations, a scale of 1:125,000, or 1" = 2 miles, is often appropriate. For more localized issues, and as a better guide to determining where detailed site studies should be undertaken, a scale of 1:24,000 may be desirable. This allows use of USGS quadrangle sheets and begins to focus on specific areas. For developments in areas with concentrations of geologic concerns, a detailed site study may be needed. For this, scales of 1" = 1,000' and 1" = 50' are often useful. The difference in the various scales is shown in Figure 3.

Map presentation

Land capability information must be displayed in a manner that will be easily understood by users of the maps. There are a number of display methods, and several different displays may be desirable, to satisfy all potential users.

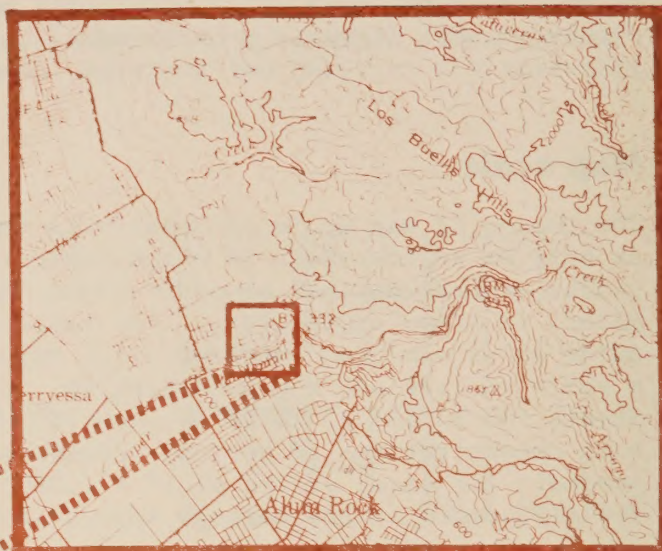
For some uses, total expected costs can be printed directly on the map. Usually, however, some aggregation into different categories, or levels, will be more useful. Categorizing costs in several different ways may help in use assessments.

Handmade maps can represent categories with either patterns or colors. Figure 4 shows some of the patterns achievable by hand, and shows the same map, computer-produced, for comparison. Many interesting methods of producing computer maps are possible. Square or rectangular line printers, with overprinted characters (Figure 4) and graphic symbols (Figure 5) can provide fairly good visual separation.

FIGURE 3

Map scale — an illustration of detail

1:125,000
(1 inch is
approximately
2 miles)



1:24,000
(1 inch is
2,000 feet)



1:10,000
(1 inch is
800 feet)



FIGURE 4

Maps produced by hand and by computer

*A hand-produced
map*



*The same map
produced by
computer*

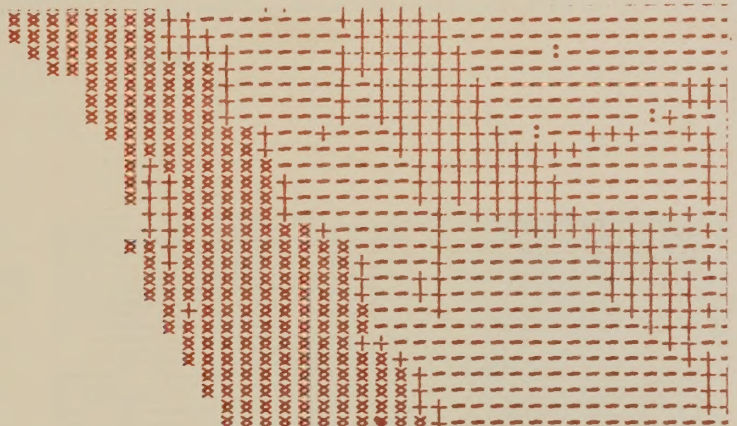
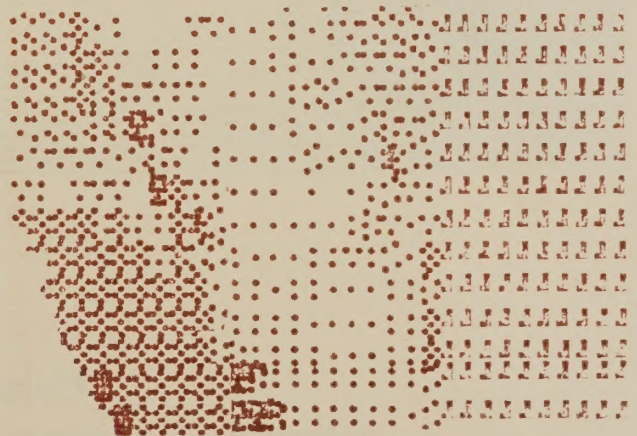


FIGURE 5

Maps using a line printer with graphic symbols



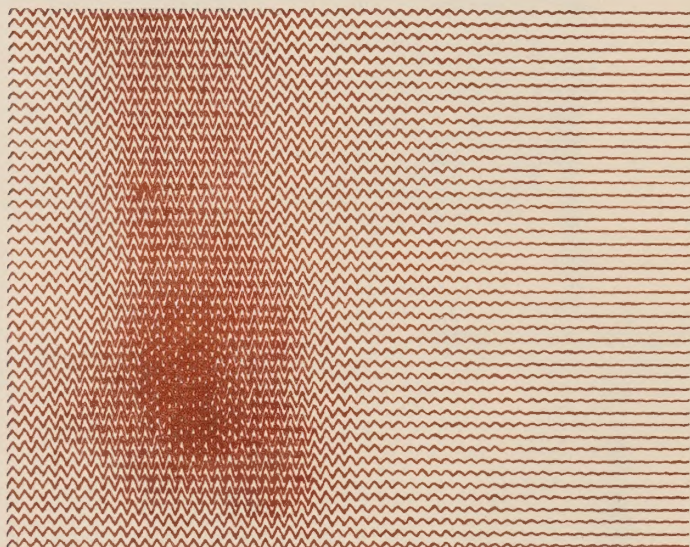
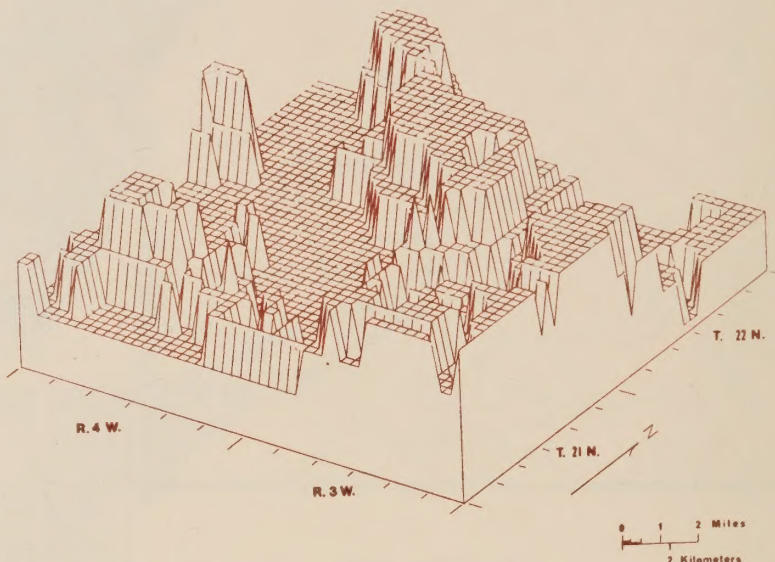
A pen plotter can be used to plot contours, draw perspectives, or produce density maps (Figure 6, below). Cathode ray tube displays, in color or black and white, can be photographed to display copy. This type of display is particularly useful if users want to test different assumptions rapidly.

FIGURE 6

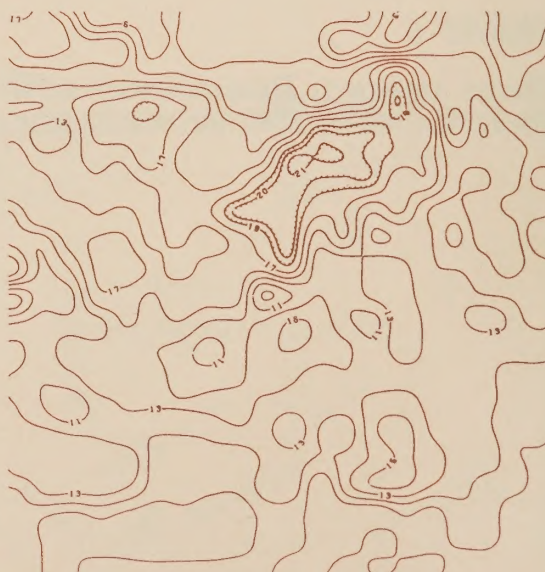
Maps from a pen plotter

Perspective

courtesy of the Geological Society of America



Density



Contours

courtesy of the Geological Society of America

DEMONSTRATION — The Santa Clara Valley.

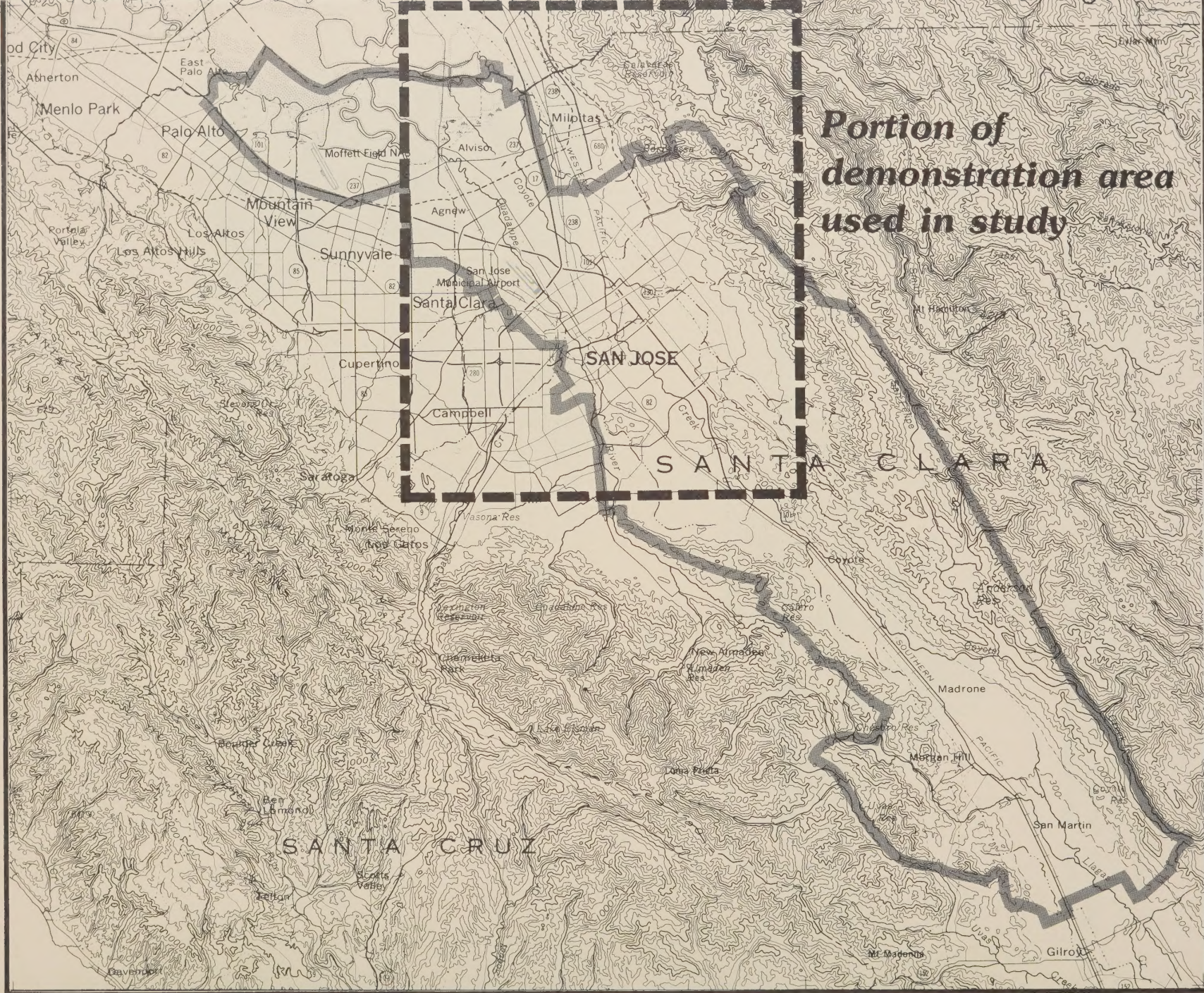


FIGURE 7 **Land Capability Study demonstration area**

DEMONSTRATION OF THE METHOD

The demonstration area

The land capability analysis method was illustrated using the Santa Clara Valley, from San Jose to Morgan Hill, as the demonstration area. In this area development pressures are mounting as a highly urbanized complex expands into a hitherto agricultural belt. The valley includes a wide range of geologic constraints and resources, and has several typical land uses.

The demonstration area maps are at a scale of 1:125,000. At this scale, a map of the entire area requires a sheet 21" x 17½". Because such large maps are difficult to produce in the quantities needed for the ABAG report, a representative portion of the area that could be reproduced on an 8½" x 11" sheet was chosen to illustrate the analysis method and concepts (see Figures 7 and 8).

Land use types

The type of land use affects the extent of geologic limitations and opportunities. In the demonstration area, eight types of land use were considered:

1. Rural or agricultural uses
2. Semirural or very low-density residential
3. Single-family residential
4. Multifamily residential
5. Regional shopping centers
6. Downtown commercial development (up to 5-story building heights)
7. Light industrial development
8. Freeways (including overpasses and interchanges).

Each land use type has distinctive building design, size, occupancy, and other characteristics, and each type can be characterized by a particular set of costs for land, utilities, improvements, buildings, and personal property and inventory. These characteristics have been defined in the ABAG study and should reflect local development.



FIGURE 8 *Portion of demonstration area used in study*

Most high-occupancy or "critical" structures were not included, because they would require a case-by-case examination that was beyond the scope of the ABAG study. This category includes hospitals, schools, police and fire stations, bridges, elevated railways, reservoirs, pipelines, and chemical plants.

Constraints and resources

The following development constraints and resources were of interest in the demonstration study:

Earthquake problems	Bearing material problems
ground shaking	shrink/swell soils
surface rupture	settlement
	liquefaction
Flooding	subsidence
stream overflow	
dam failure	Erosion and sedimentation
dike failure	
	Resources
Slope stability	sand and gravel
landslides	mercury extraction
soil creep	agriculture

Map sources

Basic Data Maps: For the demonstration area, considerable basic information was readily available:

<u>Maps and Reports on:</u>	<u>Source</u>
Active faults	California Division of Mines and Geology
	Alquist-Priolo maps
Materials (geologic) units	USGS
Slope stability	USGS
Dam inundation areas	State Division of Dam Safety; dam operators
Dike inundation areas	Santa Clara Valley Water District
Soils	USDA Soil Conservation Service
Depth to water table	USGS
Sand and gravel deposits	USGS
Mineral deposits	USGS
Erosion provinces	USGS
Ground shaking (San Andreas)	USGS method
Ground shaking (Hayward)	USGS method
Ground shaking (Calaveras)	USGS method



FIGURE 9 *Special studies zones for earthquake faults*

Some of the basic earth science information collected is easily relatable to costs, but much of the data had to be interpreted in order to produce maps of the cost associated with a particular constraint or opportunity. An attempt was made to use common map sources, to aid in the transferability of the study to other areas. The source maps were collected so that the series would depict all the study constraints and resources. As an example, the map giving basic data needed for delineating surface rupture potential is presented here as Figure 9.

Interpretive Maps: For the demonstration study, three maximum earthquake intensity maps were prepared from the basic data on geologic units and faults. The intensity categories used were: very violent (A); violent (B); very strong (C); strong (D); and weak (E). Other interpretive maps included in the demonstration were soil creep, shrink/swell, settlement, and agricultural potential.

Figure 10, showing maximum earthquake intensities for the Calaveras fault, is included here to indicate how an interpretive map displays a variety of complex information in a manner that lends itself to use by planners.

Calculating costs

Costs associated with all the constraints and resources studied were developed through in-depth analyses of each case. The choice of the type of cost to calculate was based on the assumption of standard response to the problems that characterized the study area in 1975. The practices assumed for each land use, versus each earth science constraint or resource, are summarized in Table 1. As an example, if the standard practice is to study the problem and develop mitigation measures, the costs of the study and of the engineering mitigation were calculated. If, on the other hand, no such measures were taken and if the problem is assumed to exist, future damage cost was calculated.

Aggregating capability costs and mapping capability

A computer was used to produce maps of cost attributable to geologic concerns. Data were collected using gridded transparencies with 10 cells per inch in both horizontal and vertical directions.

The modified Land Use Mapping Program (LUMP/MERGE) took the data on 13 basic data maps and an area map, and placed this information in a master file where each cell was assigned 14 variables (one for each map). Five additional data maps were created by combining the original maps; these were added to the master file as additional variables for each cell.

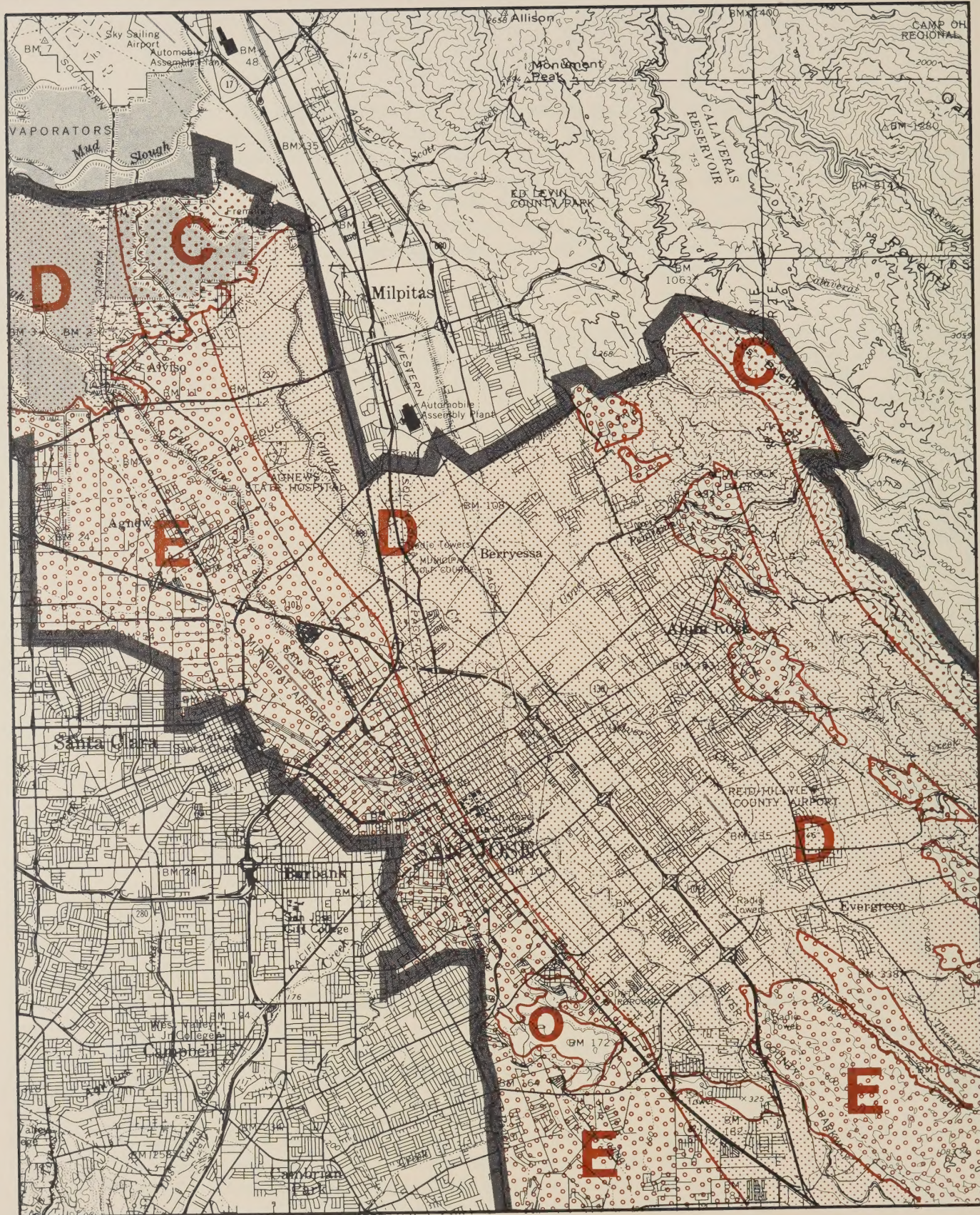


FIGURE 10 *Maximum earthquake intensities — Calaveras*

TABLE 1
**Standard response to
earth science problems
in the Santa Clara Valley, California**

LAND USE TYPE EARTH SCIENCE CONSTRAINT OR OPPORTUNITY	RURAL AGRICULTURAL	SEMI-RURAL	SINGLE-FAMILY RESIDENTIAL	MULTIFAMILY RESIDENTIAL	REGIONAL SHOPPING CENTERS	DOWNTOWN COMMERCIAL	INDUSTRIAL	FREEWAYS
SURFACE RUPTURE	B	B	A	A	A	A	A	A,B
GROUND SHAKING	B	B	B	B	B	B	B	B,D
STREAM FLOODING	B	B	B	B	B	B	B	D
DIKE FAILURE	B	B	B	B	B	B	B	D
DAM FAILURE	A,D	A,D	A,D	A,D	A,D	A,D	A,D	A,D
LANDSLIDES	A	A	A	A	A	A	A	A
SOIL CREEP	A	A	A	A	A	A	A	D
SHRINK/SWELL	A	A	A	A	A	A	A	D
LIQUEFACTION	B	B	B	B	B	B	B	D
SETTLEMENT	B	B	A	A	A	A	A	D
EROSION/SEDIMENTATION	C	C	C	C	C	C	C	C
SEPTIC TANK LIMITATIONS	D	D	D	D	D	D	D	D
SAND AND GRAVEL	D	C	C	C	C	C	C	C
MERCURY EXTRACTION	D	D	D	D	D	D	D	D
AGRICULTURE	D	C	C	C	C	C	C	C

- A. Study and Mitigate
B. Suffer Damage
C. Lose Resource Opportunity
D. No Known Cost, or Insignificant Cost

Totaling costs involved only simple addition. The LUMP/WEIGHTER computer program was employed to obtain values of expected cost and to add the cost determined for each problem or resource to the cost sum for specific cells. The resulting number in each cell represents the dollar cost per acre expected to be incurred by developing that cell with that land use.

After values were calculated for each cell, the program LUMP/MAPPER was used to produce maps which make use of overprinted symbols. Higher costs are portrayed with darker shades of gray (on a six-shade scale). An explanation is printed with each map which displays the relevant symbol, the range of total expected cost, the number of cells in each increment, and the shade of gray used for that increment.

The capability maps developed for the eight land use types in the demonstration area, and summary tables of the expected costs on which these maps are based, are presented and interpreted in the ABAG report. Space does not permit reproducing all of these figures here, but one of the draft figures and its accompanying explanation are presented as an example (see Figure 11).

Explanation for Single-Family Use Map
(Figure 11)

.....	\$1,001 to \$ 2,150 per acre
----- ----- ----- ----- -----	\$2,151 to \$ 4,630 per acre
++++++ ++++++ ++++++ ++++++ ++++++	\$4,631 to \$10,000 per acre
xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx	\$10,001 to \$21,500 per acre
 	\$21,501 to \$46,300 per acre
 	\$46,301 to \$99,999 per acre

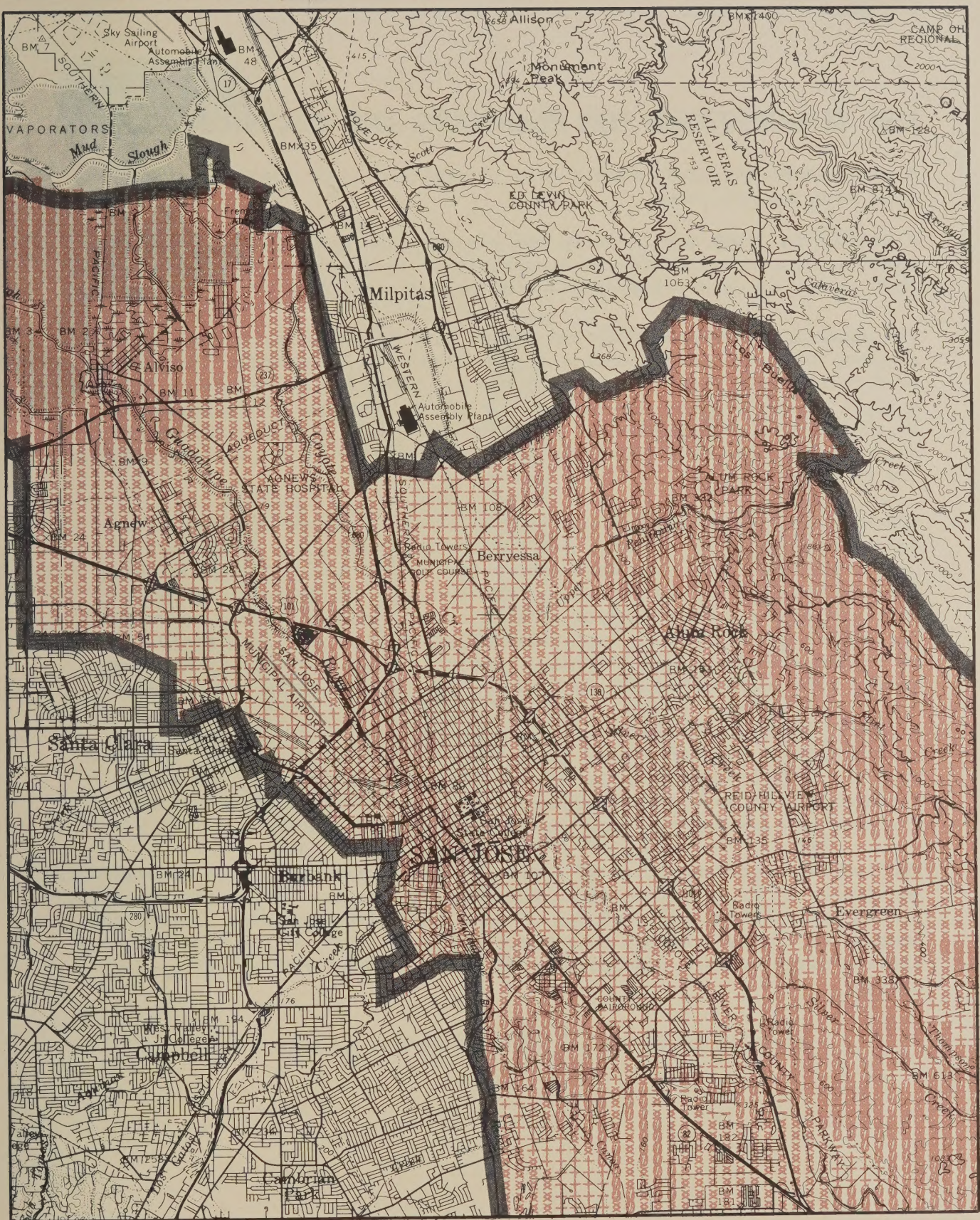


FIGURE 11 *Draft land capability map for single-family residential use*

USE SUGGESTIONS FOR PLANNERS AND DECISION MAKERS

A land capability study should help incorporate earth science information into land use decisions.

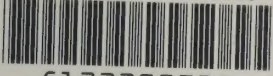
A capability study can identify the presence and magnitude of particular earth science constraints and opportunities in a locale, and hence guide that community in developing planning policies for that particular problem.

The capability assessment method can be used in the environmental review process for rapid determination of the magnitude of geologic limitations on development. This is true both for decisions as to whether to file a negative declaration and for reviews of the adequacy of environmental impact reports or statements. The most costly, or significant, earth science considerations should be examined most carefully in these reports and reviews.

The cost assessment methods detailed in the ABAG report are helpful in determining relative costs of alternative implementation programs. Here, of course, one must be aware of the limitations inherent in using dollars as a measure of social costs. Even so, the approach has wide utility. The simplest example of such a use involves surface rupture. One can either perform an investigation, find the fault, and avoid it, or one can take a chance and build randomly within the special studies zones. The costs of studies and damage can be calculated and compared.

A land capability analysis can be performed with relatively undetailed information to identify those areas where further site-specific information is needed. Equally important is the unique ability of the method to identify the most important information needed for an area because the most costly earth science considerations are identified.

The inherent characteristic of improving the quality of future information, and therefore of future studies, provides the feedback mechanism for self-controlled updating and revision of land capability analyses. Also, the process is highly amenable to incorporating new information from the various earth science disciplines, all of which are undergoing rapid change.



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"... and we can save 700 lira by not taking soil tests."

About the Association

ABAG is owned and operated by the local governments of the San Francisco Bay Area. It was established in 1961 to meet regional problems through the cooperative action of its member cities and counties. At present, 85 of 93 cities and 7 of 9 counties in the Bay Area are members. Twenty-five special districts, regional agencies and other government agencies are non-voting, cooperating members. ABAG serves an area of about 7 thousand square miles and nearly 5 million citizens.

ABAG is the areawide comprehensive planning agency for the Bay Area. Its approved Regional Plan provides a policy guide for planning of the region's:

- air quality
- airport systems
- community development
- comprehensive health services
- criminal justice
- employment
- growth management
- housing
- human services
- ocean coastline use
- open space
- seaports
- seismic safety
- solid waste management
- transportation
- water resources
- water quality

Activities include developing long-range growth policies, adopting a regional housing element, initiating community development goals and policies, and implementing a plan to preserve natural resources and manage lands in the Bay Area. ABAG also keeps citizens informed and encourages citizen participation in regional planning.

A major program during 1976 and 1977 will be the development by ABAG and other agencies of areawide air and water quality management plans for the Bay Area. The \$4.3 million effort is funded by the Environmental Protection Agency under Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

ABAG also works jointly with other regional agencies such as the Metropolitan Transportation Commission, the Bay Area Air Pollution Control District, the Bay Area Comprehensive Health Planning Council, the Bay Area Sewage Services Agency and the Coastal Zone Conservation Commissions.

ABAG policy is set by the General Assembly, which meets at least once a year. Delegates are elected officials from member cities and counties.

ABAG's Executive Board of 36 meets monthly to make operating decisions, consider grant applications, control expenditures and recommend major policies to the General Assembly. Executive Board members are appointed by County Boards of Supervisors, Mayors and City Councils. Membership on the Executive Board reflects the population size of each county.

The work of ABAG's staff of 110 is directed by the Executive Board and by policy committees that deal with various program and interest areas.

ABAG is the Federally designated areawide clearinghouse for the Bay Area. Reviews and comments on applications from local jurisdictions cover more than 150 different Federal assistance programs. During 1975, ABAG reviewed more than 1,000 local applications totalling \$555 million in Federal funds and \$748 million in total funds.

Development proposals with potentially significant effects on the region may be examined in their early stages -- before Federal grant applications are made -- by ABAG's system of hearing panels.

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